

was found that the viscosity is increased by deep and lessened during light narcosis. The specific gravity of the blood also shows regular variations. It is increased by deep and lessened by light ether narcosis. Chloroform, on the other hand, produces a slight decrease during deep and an increase during light narcosis. Hence the specific gravity cannot be regarded as an accurate index of the viscosity.

46 (92). "**Studies of the effects of radium on plants and animals,**" with demonstrations: Communicated by **WILLIAM J. GIES.**

The various studies of the effects of radium that are included in this communication were carried out at the writer's suggestion and under his general direction. All of them are still in progress. They were made possible by the generosity of Mr. Hugo Lieber, who gave the writer an abundant supply of radium bromid for each series of experiments. Professor William Hallock also encouraged the work by permitting the use of some of his valuable samples of radium bromid and radioactive substances. Dr. G. B. Pegram has given advice freely on physical matters connected with radioactivity. The studies included in this plan were the following (I-V):¹

I. "*Preliminary notes on the effects of radium rays on plants*": C. STUART GAGER (New York Botanical Garden).

The radium (bromid) has been employed in several forms, and in degrees of activity ranging from 10,000 to 1,500,000. Experiments so far indicate that the effect is the same in kind, whether the plants are stimulated with gamma rays only, or with alpha and beta rays as well. When three kinds of rays are employed the effects, within the same time, seem to be increased. The results already obtained justify the following statements:

The rays of radium act as a stimulus to plants. For this stimulus there are minimum, optimum, and maximum points, depending upon the proximity of the radium to the plant, the strength, quantity, and condition of the radium salt, the time of exposure, and the nature and state of the tissue.

The early stages of seed germination are accelerated, if stimulation ranges between the minimum and optimum points, otherwise

¹ Each of the collaborators has written the report of his own share of the investigations.

they are retarded. Seeds are less sensitive to the rays when dry than when soaked. When germinating seeds are exposed to radium at short distance, germination and subsequent growth are retarded, but when the distance between the radium and the seeds is increased and a screen of metal is interposed, growth is accelerated. Radium rays acting through soil in which plants are growing accelerate both germination and subsequent growth of the shoot, and increase the number and length of root hairs.

The growth of plants is retarded in an atmosphere of decaying radium emanations, such as may be drawn from tubes lined with Lieber's "radium coating." [See page 32 (96).] Development of leguminous tubercles is retarded when a glass tube of radium bromid (10,000 activity) is in the soil. Experiments to obtain radiotropic response have so far given negative results. Alcoholic fermentation is accelerated by radium rays.

Chloroplasts, under the influence of the rays, change their position in the cell, as when exposed to too intense sunlight. Plastids are soon over-stimulated, and their activity completely inhibited, causing etiolation and other attendant effects. Gemmæ of *Lunularia*, exposed for six days, failed to develop thalli. Meristem (embryonic tissue) of the hypocotyl is destroyed by prolonged exposure to the rays.

II. "*The action of radium rays on Amœba proteus and upon other microorganisms*": LOUIS HUSSAKOF (Laboratory of Zoölogy, Columbia University, and the American Museum of Natural History).

These experiments were intended primarily to show the influence, if any, of radium rays on the protoplasm of *Amœba proteus*. Other microorganisms (*Vorticella*, *Paramecium*, etc.) were also subjects of experiment. Radium bromid preparations of 600, 1,000, 10,000, and 1,500,000 activity (in thin glass tubes) were used, and several celluloid rods covered with Lieber's "radium coatings" [page 32 (96)] of 10,000 to 25,000 activity were also employed. The radium container was held in the water within from 1 mm. to 3 mm. of the organism under observation.

Under these conditions no visible effects were produced, by even the strongest radium preparations, during periods of observation of about an hour. The water surrounding the animal may have prevented radiant effects.

III. "*The effects of intravenous injections of radium bromid*": RUSSELL BURTON-OPITZ and G. M. MEYER (Physiological Laboratory, Columbia University).

These experiments, dealing principally with the effects of radium bromid upon the circulation and respiration, were performed upon dogs weighing from 4 to 5 kilos. Light ether-narcosis was employed. The solutions injected contained 1.8 mg. of radium bromid per c.c. of distilled water. Preparations of radium bromid of 240, 1,000, and 10,000 activity were used. The facial vein was selected for the injections.

Injection was always followed, after a latent period of about five seconds, by a gradual and well marked increase in blood-pressure, this rise evidently being caused by general vaso-constriction. Soon, however, a marked decrease in the frequency of the heart, accompanied by a pronounced irregularity, causes a fall in pressure. Contractions in which the diastolic phase is extremely conspicuous interchange with a series of forcible preëminently systolic beats. It need hardly be mentioned that under these conditions the variations in blood-pressure are extreme. These effects of radium occur also after both vagi have been divided.

The circulatory effects are accompanied by a gradual decrease in the frequency of respiration, terminating finally in complete respiratory paralysis. This effect precedes the total inhibition of the heart.

All ordinary preparations of radium salts contain barium. In order to check the effects of such impurities, the authors carried out a number of comparative experiments with pure barium bromid. It was found that the effects of radium bromid preparations of low activity (240 and 1,000) differ only quantitatively from those of barium bromid. Certain amounts of such radium preparations produce effects that can be obtained only by correspondingly larger amounts of barium bromid. The influence of barium in causing pronounced irregularity of the heart is not evidenced by the preparations of radium bromid of 10,000 activity; only a marked inhibition results, which is accompanied by a decided rise in blood-pressure.

IV. "*The radioactivity of the different organs after intravenous injections of radium bromid*": GUSTAVE M. MEYER (Laboratories of Physiological Chemistry and Physics, Columbia University).

The radioactivity of the different organs of dogs experimented upon was determined by two methods. For an approximate estimation of radioactivity, the gold leaf electroscope has been found very serviceable. In this case, it is only necessary to thoroughly dry the finely divided organ and note the rapidity with which the charged gold leaf descends. The use of the quadrant electrometer admits of a more exact valuation of the radioactivity. The organ is incinerated and the radioactivity of the ash determined.

The determinations thus far made have been entirely upon the dogs used in the experiments of Burton-Opitz and Meyer (III). The following parts have been examined: Blood, liver, lungs, kidney, spleen, pancreas, brain, and muscle. Of these, the blood showed the greatest activity, while the brain has so far given negative results.

Injection as well as feeding experiments are in progress.

V. "*The influence of radium bromid on metabolism in dogs*": WILLIAM N. BERG and WILLIAM H. WELKER (Laboratory of Physiological Chemistry, Columbia University).

The experiments are being carried out on dogs in nitrogenous equilibrium. Radium bromid preparations of 240, 1,000, and 10,000 activity have been employed. Thus far introduction has been by mouth only. One animal (6.6 kilos) has been fed 1.1 gm. 240 activity, 0.25 gm. 1,000 activity, and 0.125 gm. 10,000 activity in small amounts daily (during 12 days), without causing any gross symptoms, except diarrhea during the period of administration of the preparation of 240 activity with its large content of barium. Protein metabolism did not appear to be materially affected. Total sulfate (SO_4) in the urine was markedly increased, especially during the period following the administration of the preparation of highest activity, and when diarrhea as well as constipation was entirely absent.

In control experiments with barium bromid, much larger quantities per os (as much as 0.5 gm. daily to a dog weighing only 4.5 kilos) were without any gross symptoms whatever. In the case of barium, also, protein metabolism was practically unaffected by the quantities used. The quantity of total sulfate in the urine, unlike the result with radium, appeared to be practically unaffected by the barium bromid.

Injection experiments with both barium and radium will soon be completed.